Sierra Nevada speleothems: Potential as high-resolution archives of changes in atmospheric circulation over California

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What is a speleothem?

Speleothems are secondary minerals that precipitate from groundwater dripping, flowing or standing still within a cave. Speleothems grow in layers, similar to tree rings, and they can grow continuously for 1000s to 100,000s of years. Most often, speleothems are made up of calcite (calcium carbonate), and they come in many forms including stalagmites and stalactites (Fig. 1).

Figure 1: Stalagmites (1), and stalactites (2) in Black Chasm Caverns in Volcano, California.

How are speleothems used in paleoclimate research?

Speleothems are useful tools for paleoclimate research because they capture the cave's response to changes in the external environment. During growth, the minerals preserve changes in air temperature and precipitation above the cave. To create a climate record, the layers (Fig. 2) can be sampled and analyzed for both ***time*** (U-series dating) and ***climate*** (e.g., oxygen isotopes). Thus, by using speleothems, past changes in temperature and rainfall above caves are preserved and can be correlated to regional and global climatic shifts through time.

Figure 2: A. Using a coring drill to sample through the growth center of a stalagmite in Boyden Cave. **B**. Part of a stalagmite core from Moaning Cave in Vallecito, California. The core has been cut in half and polished to reveal horizontal growth bands. The sample pictured is 7cm.

Where do speleothems occur in California?

Speleothem-bearing caves are present throughout the Coast Ranges and the Sierra Nevada of California. The caves included in this study are developed in limestone and marble terranes distributed throughout the western Sierra Nevada and define a N-S transect from 40.8 N to 37.16 N (Fig. 3).

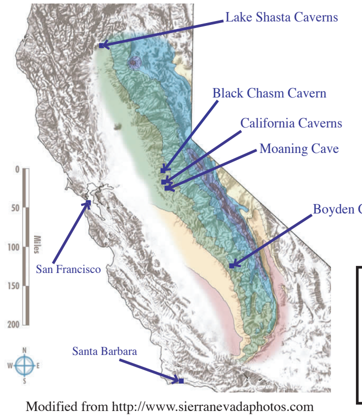
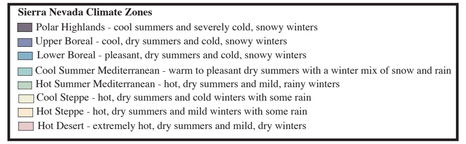


Figure 3: Modern climate zones within the Sierra Nevada with locations of caves to be included in this study. Most caves fall within the Hot Summer Mediterranean climate zone (green). The area around Boyden Cave experiences colder winters with more snowfall (aqua).



How far back do Sierra Nevada speleothem records go?

Initial uranium-series dating of a speleothem from Moaning Cave indicates that these records extend back to at least 20,000 years (20 kyrs) to the Last Glacial Maximum (Fig. 4). However, $^{26}Al/^{10}Be$ dating of cave sediments from the southern Sierra Nevada indicates that the record could potentially extend to 2.7 million years.

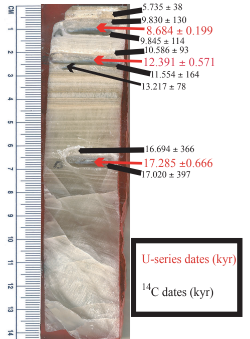


Figure 4: Core sample from Moaning Cave subsampled for dating by uranium-series and radiocarbon methods. As the stalagmite was actively growing during collection, the topmost calcite is considered to have formed recently. U-series dating of speleothems is highly accurate but requires large sample sizes. Radiocarbon dating requires much smaller samples, but is complicated by dead carbon input from the cave host rock. Radiocarbon ages can provide helpful insight into changes in precipitation rate and groundwater - host rock interactions. The U-series analyses were conducted at at the Berkeley Geochronology Center and the radiocarbon analyses at Lawrence Livermore National Lab.

What can speleothems tell us about climate change in California?

Speleothems contain climatic proxy records, including oxygen and carbon isotopes and Mg and Sr concentrations. A shift to higher isotopic values and trace element concentrations, such as occurred between 7.5 and 7 kyr (Fig. 6), indicates drier conditions and increased water-rock interactions in the host rock. This increased aridity may reflect a long-term northward shift of the polar jet stream, which currently delivers winter rains to California (Fig. 5). In contrast, a long-term southward shift in the jet stream position has been hypothesized for the Last Glacial Maximum, which could have brought increased rainy weather to California year-round. As such, our latitudinal transect of Sierra Nevadan speleothem records provide a detailed archive of the north-south polar jet migration over the past 20 kyrs.

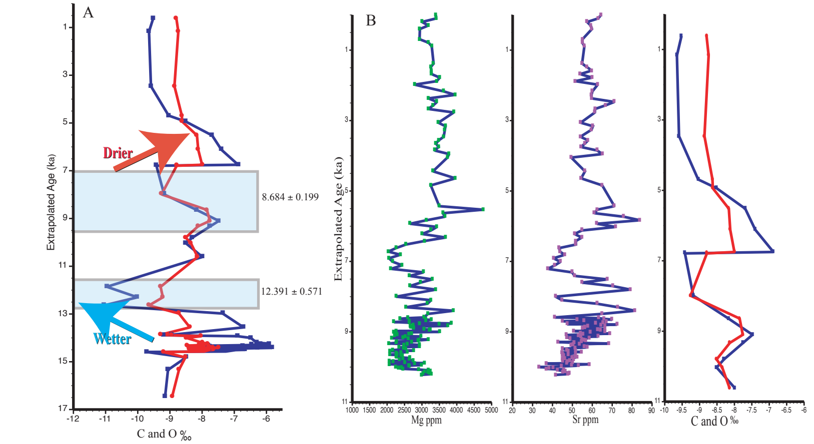


Figure 6: A. Oxygen (red) and carbon (blue) stable isotope records for the Moaning Cave sample plotted versus extrapolated age (17 kyr to present). Locations of samples for U-series ages are given by blue boxes. **B**. Mg and Sr concentrations versus age (11 kyr to present) shown with part of the stable isotope record (from A). Oxygen isotope values decrease during the Younger Dryas (13 - 11.2 kyrs BP), possibly due to increased precipitation or decreased temperature.

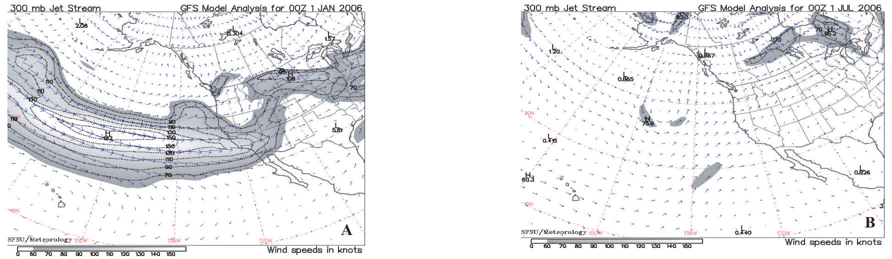


Figure 5: Jet stream maps for western North American on January 1st (**A**) and July 1st (**B**) 2006. These maps show the pattern of winds approximately 32,000 feet above the land surface. Contours of wind speed are shaded in gray, and wind vectors are shown in blue. The gray envelope represents the position of the polar jet stream. Maps courtesy of the California Regional Weather Server.